researches, connected with some of the most obscure and difficult problems of Archæology. Allow me to add, that the merit of those researches, high as it is in itself, is enhanced in your case by the circumstance, that they have been pursued in the seclusion of retirement, and without any of those aids derived from the intercourse with others engaged in similar pursuits, which are usually so effective in impelling to and suggesting inquiry.

The President, presenting the Medal to Mr. O'Donovan, addressed him thus:

Mr. O'Donovan,—Accept this Medal as a testimony of the high value which the Council of the Royal Irish Academy set upon your labours connected with Irish philology, and Irish history and antiquities. This is the first occasion on which the Council, acting on the laws recently enacted by the Academy, have conferred the honour of the Cunningham Medal for works not published in the Transactions of the Academy. They therefore hope that you (and through you the literary public) will receive this award, not only as a just tribute to the value of your own researches, but also as a token of their sympathy with all who are engaged in the common pursuit of truth.

Mr. Robert Ball, Treasurer, presented an ancient silver pin of a very peculiar form, on behalf of John Mac Donnell, M. D. He also exhibited a large collection of casts of fossils, lately presented to the Museum of Trinity College by the East India Company.

The following communication on the dynamic effect of a turbine, as shown by the application of Prony's brake, was received from the Rev. T. R. Robinson, D. D.

This wheel was constructed for William Kirk, Esq., by the Messrs. Gardner, of Armagh. These gentlemen had been strongly impressed with the advantages of this wheel, by reading the account of it given by Sir Robert Kane, in the "Industrial Resources of Ireland;" and one of them actually

visited France for the purpose of establishing relations with its inventor, which might enable them to introduce it as a moving power in this active manufacturing district. Finding it impossible to make any satisfactory arrangement with M. Fourneyron, they instituted a series of experiments, guided by which they succeeded in constructing the present machine, which seems to be very efficient; and as little is known in this country of the turbine, Dr. Robinson thinks the results he obtained may have some interest.

It drives eight beetling engines. In these a series of wooden stampers are raised by wipers on a revolving beam, and allowed to fall on the linen, which is rolled on a massive cylinder, sixty times in a minute, the cylinder itself revolving slowly, and being traversed in the direction of its axis. Each engine has thirty-six, weighing each twenty pounds and lifted twelve inches. The supply of water is very limited, being derived from the tail race of a mill situated higher on the water-course, and very deficient in summer; while in winter there is much back-water.

The turbine (a distinct idea of which can easily be obtained from a work of Rühlman, recently translated by Sir Robert Kane) has thirty-six floats, which are perpendicular to the circumference at their origin, and receive the water at an angle of 45°. These are attached by flanches, which, in Dr. Robinson's opinion, present a good deal of resistance to the efflux of the water, and absorb power. The internal diameter is 2·40 feet, and the external 4·80; the depth is 7·5 inches, divided into four compartments, which can be worked partially, and each of which can drive two engines.

In estimating the dynamic effect of a water-wheel, we must know the impelling power, and the resistance overcome with a given speed. The first is the weight of the water expended in a given time, multiplied by the height through which it has descended; this involves the measurement of the water, which, in Dr. Robinson's experiments, was made by an over-

fall established immediately below a bridge about 100 feet from the turbine. This process gives very precise results, if the necessary precautions be taken. The formula for the number of cubic feet passed in a second is $Q = C \times L \times \overline{H}|^{\frac{3}{2}}$, when C is a coefficient varying from 3·550 to 3·206, according to the ratio of the overfall's width to the channel in which it is placed. The first belongs to the case when they are equal, the second when that ratio does not exceed 1 to 3. L is the breadth of the overfall in feet, and H the depth of the water in it. This should be measured so far behind it as to be exempt from the curvature assumed by the surface as the water rushes towards the aperture. The measures were taken, for convenience, at the overfall itself, and it was found by trial that they require to be multiplied by 1·111, in the circumstances of this overfall, to reduce them to those due to the undisturbed surface. This formula, however, assumes that the water-way above is so large, that the velocity of arrival at the overfall is insensible. If not, the result must be multiplied by $\sqrt{\left(1 + \frac{0{\cdot}1395 \times u^2}{H}\right)}$; u being this velocity, which Dr. Robinson obtained by dividing the approximate quantity of water given by the formula, by the water-way of the channel. This last was found, by a careful section, to be 12·18 feet + $\frac{7}{8}$ of a foot for every inch of water in the overfall. The results obtained are, he believes, quite as exact as direct measurement could afford. The fall was ascertained by measuring, at the beginning and end of each experiment, the distance of the upper surface of the water below a point fourteen feet above the top of the turbine, and also the depth of water over that top (the wheel being always submerged). The power of the fall is expressed in horse power, whose unit is 33,000.

The resistance in ordinary work is, first, the friction of the machinery, and secondly, the weight of the beetles; these he at first thought could easily be valued, and thus give a measure of the efficiency of the machine. As, however, the

beetles spring up by their own elasticity and that of the linen, and are overtaken by the wipers in their ascent, their whole weight does not resist. Indeed Dr. Robinson is not aware of any unexceptionable mode, except Prony's brake, which can exhibit the actual amount of actual force transmitted by a machine. This instrument is well known to consist of a ring clamped on a revolving cylinder, and tightened till its friction constrains the shaft to revolve at a given speed. That friction must equal the resistance of any other kind of work which produces the same speed; and it can be directly measured by weights hung on the extremity of a lever attached to the ring. Let R be the distance of the weight from the centre of the shaft, r the radius of the brake, n the revolutions which it makes in a minute, W the weight applied + that of the lever reduced to the same distance R; w the friction produced by the ring and its appendages. Then the effect is expressed by the equation.

$$E = \frac{2\pi r \times \left\{ \frac{W \times R}{r} + w \right\} \times n}{33{,}000}$$

In this instance $\frac{R}{r} = 19$, and $r = 0{\cdot}56$. The weight of the lever reduced to $R = 50$ lbs; and as the pressure of the brake, &c., $= 202$ lbs, while, from the abrading nature of the action,* the coefficient of friction must have been at least one-fifth, the quantity w may be taken at 40 lbs. These give the formula

$$E = (w + 52{\cdot}132) \times n \times 0{\cdot}002015.$$

In the first trial, the weight $W = 280$lb.; the depth on the overfall $= 4{\cdot}75$ inches; the mean depth from the datum plane

* This was so severe, owing to the rubbing surface being too small, that it was necessary to have the upper part of the brake made a cistern, which was kept full of water, and communicated with the rubbing parts by several apertures. The water boiled violently from the heat evolved.

above, 15·75 inches; and that on the turbine thirteen inches, the water being dammed up by the overfall. The brake made nineteen revolutions in seventy-five seconds, equivalent to 70·1 of the turbine, or 23·59 of the wiper beam, per minute.

Hence Dr. Robinson computed

$$Q = 9{\cdot}41\text{ ; Power} = 12{\cdot}38\text{; } E = 10{\cdot}17\text{ ; and } \frac{E}{P} = 0{\cdot}821.$$

The last number, the ratio of the work done to the power, is evidently the measure of the value of the machine, and though it is very high, Dr. Robinson is confident that it is not overrated.

The second trial was intended to observe the effect of a higher speed, and showed a remarkable diminution of effect. There $W = 224$lbs.; $H = 5{\cdot}125$ inches; the depth above 11·75 inches; that on the turbine the same as before; and the speed nineteen in sixty-six seconds, equivalent to 79·6 of the turbine, or 26·81 of the wiper beam. These data give:

$$Q = 10{\cdot}59\text{ ; } P = 14{\cdot}43\text{ ; } E = 9.61\text{ ; and } \frac{E}{P} = 0.667.$$

At a third experiment the brake came off the shaft, but, fortunately, without doing any harm to the workmen; and Dr. Robinson did not think it prudent to replace it. He, however, hopes to repeat these trials, with a brake of larger dimensions, on another turbine that is in process of construction.

The great loss of effect by increasing the speed induced Dr. Robinson to suspect that some error must have occurred; but Mr. Kirk had observed that, by varying the number of engines, and counting the revolutions in each case, more work seemed to be performed at slow speeds. This was tried with the addition of the same overfall, to ascertain the power expended in each trial, and the results obtained, though not absolute measures, appear to Dr. Robinson worthy of notice, as they may assist the theory of these machines. The measures of the power, however, differ from the preceding, as the

depth on the turbine was not measured. Instead of it, the depth at the overfall is deducted: this is less than the truth, and therefore the powers given are something too high.

The experiments were made thus. One compartment of the turbine being opened, the beetles of all the engines were suspended, and the revolutions of the wiper beam, per minute, counted. The resistance here is merely the friction of the gearing of the eight engines, $= g$. Then bring one set of beetles into action, the resistance is $g + \varepsilon$, and so on. Repeat the same with two and three compartments. With one, however, only four engines could be worked, and with the others it was thought unsafe to try g alone. The results obtained are given in the following table, of which the last column alone requires explanation. It contains the resistance in terms of g and ε, multiplied by a coefficient which is the number of revolutions divided by the power, or that which a unit of horse power would produce.

No.	Revol.	Compartments.	Fall.	Q.	P.	E	$= g \times$
1	26·30	1	12·40	6·36	8·94	$2·943 \times g$	2·943
2	23·20	1	12·45	5·76	8·12	$2·856 \times (g+\varepsilon)$	3·812
3	17·63	1	12·14	5·55	7·64	$2·308 \times (g+2\varepsilon)$	3·854
4	16·56	1	12·20	5·55	7·68	$2·157 \times (g+3\varepsilon)$	4·324
5	12·20	1	12·04	5·71	7·79	$1·565 \times (g+4\varepsilon)$	3·661
6	32·14	2	12·08	12·53	17·15	$1·874 \times (g+\varepsilon)$	2·502
7	30·00	2	11·94	12·22	16·53	$1·815 \times (g+2\varepsilon)$	3·031
8	27·93	2	12·15	11·69	16·09	$1·736 \times (g+3\varepsilon)$	3·480
9	25·42	2	11·93	11·74	15·87	$1·602 \times (g+4\varepsilon)$	3·748
10	22·48	2	11·67	11·30	14·95	$1·504 \times (g+5\varepsilon)$	4·022
11	19·72	2	11·42	11·04	14·28	$1·381 \times (g+6\varepsilon)$	4·156
12	17·29	2	11·46	11·23	14·59	$1·185 \times (g+7\varepsilon)$	3·963
13	14·00	2	11·35	11·15	14·36	$0·975 \times (g+8\varepsilon)$	3·587
14	32·88	3	11·69	17·67	23·41	$1·405 \times (g+3\varepsilon)$	2·817
15	30·93	3	11·65	17·56	23·17	$1·335 \times (g+4\varepsilon)$	3·123
16	28·00	3	11·25	16·65	21·22	$1·319 \times (g+5\varepsilon)$	3·528
17	26·35	3	11·29	16·89	21·60	$1·220 \times (g+6\varepsilon)$	3·671
18	24·24	3	11·30	16·50	21·13	$1·147 \times (g+7\varepsilon)$	3·836
19	20·86	3	10·92	15·85	19·62	$1·063 \times (g+8\varepsilon)$	3·911

The effect of the speed is evident by comparing, for example, Nos. 4, 8, and 14, where the load is the same number. However, when it is equal, the effect per horse power must be the same. By equating the values of E, under this condition, the relation of g and ε may be determined. Thus, Nos. 16 and 8 gave

$$1{\cdot}319\ (g + 5\,\varepsilon) = 1{\cdot}736\ (g + 3\,\varepsilon)\,;$$

from which

$$\varepsilon = g \times 0{\cdot}3240.$$

The mean of eight such* gives it $= g \times 0{\cdot}3349$ with no very great discordance; and substituting this value in E, the numbers given in the last column of the table are the result.

Taking means of those that are adjacent, and arranging them according to the revolutions of the turbine, per minute, they give:

Mean of	Revol.	Effect.
Nos. 3, 13	38·9	3·624
4, 12, 3	51·0	4·035
11, 19, 10	62·4	4·030
2, 18	70·4	3·824
9, 17	76·9	3·709
8, 16	83·0	3·504
7, 15	90·5	3·077
6, 14	96·6	2·654

It seems from this that the maximum effect is produced when it makes about fifty-four revolutions per minute; and that the effects at the speeds which correspond to those of the brake experiments are nearly in the same ratio.

Some practical results may be deduced.

1. The close approximation of the values of $\frac{\varepsilon}{g}$ shows that

* When the speed is not exactly the same, interpolation is used.

the machine is equally efficient with one or several compartments open. It is least with the higher speeds, and *vice versâ*, as might be expected from the elasticity of the beetles being more active in the former case; but there is no difference which cannot be explained by this cause.

2. The quantity of water discharged in these experiments is scarcely more than half what is due to the head and water-way of the sluice. This was entirely unexpected; for in Barker's mill and other *reactive* wheels of the same kind, the centrifugal force increases the discharge; and nearly half the whole power is thus absorbed.

From the drawing of this turbine supplied by Messrs. Gardner, it appears that the effective water-way of the sluice, with three compartments open,* is 1·86 feet. From this and the column 2, the velocity with which the water enters the turbine can be computed; and Dr. Robinson finds that when the speed is seventy-two revolutions it enters *without shock*, a condition considered by Poncelet and others, who have treated of this wheel, to be essential. Here, however, the maximum is at a much lower velocity; from which it may be inferred that the theory of the turbine requires in this respect some modification. On the other hand, if Rühlman's details and plate of the St. Blas turbine (the most remarkable that has yet been constructed) are exact, it deviates from this rule far on the other side, revolving with more than twice the speed due to this condition. It seems, therefore, that the theory of the turbine requires some revision.

On the whole, Dr. Robinson is of opinion that the turbine is a very valuable motive agent, even should it not fully realize the highest statements of its efficiency which have been made on the Continent. He has not yet been able to compare

* At the time of these experiments the permanent supply of water was only ten cubic feet, which will explain the diminution of fall as they proceeded.

it directly with the ordinary water-wheels, for the brake could not be applied without much inconvenience in any of Mr. Kirk's other mills; nor can any inference be made from the power applied to drive them, for the friction, &c., differs too much in each. For instance, measuring the quantity g, the friction of the machinery of eight engines, it was in that belonging to the turbine 4·74 horse power, when working at the normal speed; 3·45 at another mill; and only 2·82 at a third. That of the beetles is probably equally variable. But he sees no reason for doubting the results obtained with the brake, the lowest of which is scarcely exceeded by the best overshot wheels, while the others surpass considerably the usual estimate of their performance. The small bulk and weight are decided advantages (except in variable resistances, where the momentum of a large wheel acts as a fly). It seems peculiarly applicable to very high falls, having the special advantage of lessening in size and cost as the fall increases; and its power of acting with undiminished effect, when totally submerged, fits it for many situations where ordinary water wheels are impeded at times by back-water.